Differentiated RWA Algorithm Providing QoS Recovery in the Next Generation Backbone Network based on DWDM

Jung-Hyun Bae*, Hyun-Su Song*, Hyun-Jin Lee+, Young-Boo Kim+, Sung-Un Kim*
*Department of Telematics Engineering, Pukyung National University
+Network Architecture Team, Electronics and Telecommunications Research Institute

DWDM 기반의 차세대 백본망에서 QoS Recovery를 제공하는 차등적인 RWA 알고리즘

배정현*, 송현수*, 이현진+, 김영부+, 김성운*
*부경대학교 정보통신공학과
+한국전자통신연구원 네트워크구조팀
E-mail: *{bluefull; dukesong@mail1.pknu.ac.kr, kimsu@pknu.ac.kr}, +{petrus;ybkim@etri.re.kr}

Abstract

In the next generation backbone networks based on dense-wavelength division multiplexing (DWDM), the routing and wavelength assignment with quality-of-service (QoS) recovery is essentially needed to support a wide range of communication-intensive and real-time multimedia services. This paper proposes a new dynamic routing method called as MW-MIPR (MultiWavelength-Minimum Interference Path Routing), which chooses a route that does not interfere too much with many potential future connection requests. This paper also proposes a differentiated RWA mechanisms combined with MW-MIPR algorithm to provide QoS recovery for various multimedia applications in the next generation backbone networks based on DWDM.

I. 서론

The dense-wavelength division multiplexing (DWDM) networks have been widely accepted as a promising approach to the next generation backbone networks for nation wide or global coverage [1]. The survivability in DWDM networks is more important problem because a single failure can cause loss of vast traffic volumes [2]. The routing and wavelength assignment with quality-of-service (QoS) recovery is essentially needed to the foundation and success of next generation backbone networks expected to support a wide range of communication-intensive and real-time multimedia applications. But the existing RWA schemes without considering potential traffic demands cannot also provide satisfied QoS recovery for each service in the next generation backbone networks based on DWDM.

To overcome this problem, we propose a new dynamic routing method called as MW-MIPR (MultiWavelength-Minimum Interference Path Routing), which chooses a route that does not interfere too much with many potential future connection requests. This paper also proposes a differentiated RWA mechanisms combined with MW-MIPR algorithm to provide QoS recovery for various multimedia applications in the next generation backbone networks based on DWDM. In the simulated results, proposed MW-MIPR algorithm achieves more improvement in blocking probability than previous routing algorithms and differentiated RWA mechanism by applying MW-MIPR algorithm provides more reliable and stable QoS guarantees in terms of survivability rate.

The remainder of the paper is organized as follows. In section II, we propose a new dynamic routing algorithm with consideration for potential connection requests in DWDM networks. In section III, we take into account differentiated RWA mechanisms to provide QoS recovery for various

본 논문은 한국과학재단 목적기초연구(R01-2003-000-10526-0) 지원으로 수행되었음.

multimedia services in the next generation backbone networks Simulation results and conclusions are presented in section IV and V, respectively.

II. MW-MIPR Algorithm

Generally, the routing under consideration for network's status is more and more important to improve wavelength utilization [3]. In this paper, we propose MW-MIPR algorithm as a new dynamic routing algorithm with consideration for potential block possibility of future traffic demands.

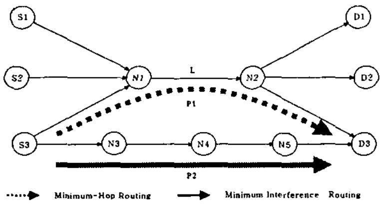

Fig. 1. MW-MIPR Algorithm
(그림 1. MW-MIPR 알고리즘)

Proposed algorithm chooses a route that does minimize interference for many potential future connection requests by avoiding congestion links. For an example as shown in Fig. 1, Mw-MIPR is to pick route P2 for connection between (S_3, D_3) pair that has a minimum affect for other connection requests (S_1, D_1) as well as (S_2, D_2) even though the path is longer than P1 with a congested link L. Before the description of MW-MIPR algorithm, we define some notations commonly used in this algorithm as follows.

• $G(N,L,W)$: The given network, where N is the set of nodes, L is the set of links and W is the set of wavelengths per link. In this graph, W is same for each link l that belongs to L i.e., $\forall l \in L$

• M : Set of potential source-destination node pairs that can request connection in future. Let (s,d) denote a generic element of this set

• p_{sd} : The minimum hop lightpath between a (s,d) pair, where $\forall(s,d) \in$ M.

• π_{sd} : Set of links over the minimum hop path p_{sd}

• $R(l)$: The number of currently available wavelengths on a link l, where $\forall l \in L$

• Λ_{sd} : The union set of available wavelengths on each link l, where $\forall l \in \pi_{sd}$

• F_{sd} : The set of available wavelengths on bottleneck link that has the smallest residual wavelengths among all links within π_{sd} i.e., $\forall l \in \pi_{sd}$ (if all nodes in the network have wavelength-continuity constraint, then F_{sd} is equal to Λ_{sd})

• Ω_{sd} : Set of wavelengths assigned to the minimum hop path p_{sd}

• C_{sd} : Set of critical links for a (s,d) pair, where $\forall(s,d) \in$ M. This parameter indicates links which belong to π_{sd} and are shared on the minimum hop paths of other node pairs at the same time.

• α_{sd} : The weight for a (s,d) pair, where $\forall(s,d) \in$ M.

• Δ : A threshold value of available wavelengths on a link (20 % ~ 30 % of W)

2.1 MW-MIPR in a network with full wavelength conversion capability

In DWDM network, the wavelength-continuity constraint can be eliminated if a wavelength converter is at a node [3]. Especially, in the network made of nodes with full WC (Wavelength Conversion) capability from any wavelength to any other one, a wavelength can be easily assigned if a residual wavelength is on links over selected route. Based on notations such as C_{sd} and Δ, we choose the minimum interference path for potential future demands by considering critical links as well as non-critical links with few wavelengths. Equation (1) determines links with congestion possibility between (s,d) pair in the network with full WC capability, where $\forall(s,d) \in \mathrm{M} \setminus (a,b)$ and $\forall l \in L$, and call them CL_WC_{sd}.

$$CL\_WC_{sd} : (l \in C_{sd}) \cap (R(l) < \Delta) \qquad (1)$$

MW-MIPR algorithm gives appropriate weights to each link based on amount of available wavelengths on a link l where $\forall l \in L$, so that the current request does not interfere too much with potential future demands. The link weights are estimated by the following procedures. First, let $\partial F_{sd} / \partial R(l)$ indicates the change of available wavelengths on the bottleneck link l for the potential connection request between a (s,d) pair. Then, the weight $w(l)$ of a link $\forall l \in L$ is set to

$$w(l) = \sum_{(s,d) \in M \setminus (a,b)} \alpha_{sd} (\partial F_{sd} / \partial R(l)), \qquad (2)$$

Equation (2) determines the weight of each link for all (s,d) pairs in the set M except the current request when setting up a connection between the (a,b) pair i.e., $(s,d) \in \mathrm{M} \setminus (a,b)$, computing weights for all links is very hard, where $\forall l \in L$. To solve this problem, we consider more restricted link with Equation (3) if a link belongs to the set of congestion links for certain (s,d) pair i.e., $l \in CL\_WC_{sd}$.

$$\begin{cases} \partial F_{sd} / \partial R(l) = 1 & [if\ (s,d) : l \in CL\_WC_{sd}] \\ \partial F_{sd} / \partial R(l) = 0 & [otherwise] \end{cases} \qquad (3)$$

$$w(l) = \sum_{(s,d): l \in CL\_WC_{sd}} \alpha_{sd} \qquad (4)$$

Therefore, computing weight for each link is simplified as shown in Equation (4). Based on above formulations, MW-MIPR algorithm is given as Fig. 2. Once the weight of each link l where $\forall l \in L$ is determined, MW-MIPR routes the current traffic between (a,b) pair along the path with the smallest $w(l)$. If there is a tie, then min-hop path routing will be used to break the tie. We accomplish RWA problem in a network with full WC capability through following procedures.

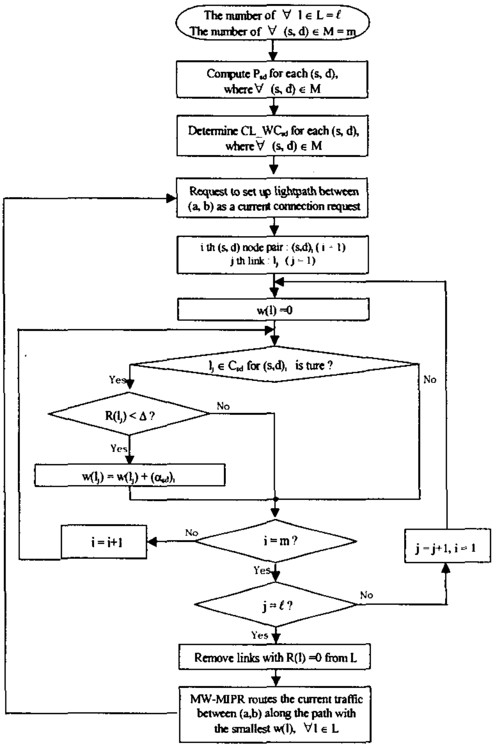

Fig. 2. MW-MIPR in a network with full WC capability
(그림 2. 전파장 변환 능력을 지닌 망에서 MW-MIPR 알고리즘)

2.2 Simulation Results

In this sub-section, simulations are carried out to evaluate the performance of MW-MIPR in terms of connection blocking probability. Topology used in simulations is NSFnet that is consisted of 14 nodes, 20 links and a single fiber. We choose 5 pairs as the set of potential source-destination node pairs M for our simulations.

In a network with full WC capability, proposed MW-MIPR has performance improved by about 10 % compared to the existing routing (FR: Fixed Routing and DR: Dynamic Routing) algorithms as shown in Fig. 3.

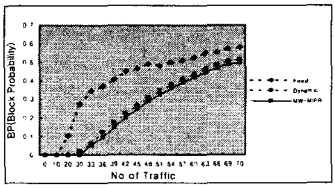

Fig. 3. Comparison of FR, DR and MW-MIPR algorithm
(그림 3. DR, FR, MW-MIPR 알고리즘 성능 비교)

III. Differentiated RWA Algorithm with QoS Recovery

In the generation high-speed backbone network based on DWDM, QoS recovery is a important issue to provide guaranteed QoS for a wide variety of multimedia services [4]. But it is very inefficient that 100% resilience guarantee is provided to all various traffic with differentiated QoS level.

In this paper, we propose differentiated RWA providing QoS recovery for Diffserv (Differentiated services) model as follows:

(a). The more an optical signal passes nodes consisted of OXC(Optical Cross-Connects), OADM(Optical Add-Drop Multiplexer) and wavelength converter, the more the quality of optical signal falls. Thus premium service and assured service that require high quality would be routed along shortest path selected by optical signal-to-noise ratio (OSNR) constraints of each service class regardless of amount of residual wavelength on a link. And then, proposed MW-MIPR algorithm is applied for best-effort service to protect QoS recovery for services with high QoS level.

(b). Signal parameter like wavelength can change by vulnerabilities on the level of network components or various impairments such as attenuation and dispersion. Considering these attributes of wavelength, premium services with the highest QoS assurance should be assigned to wavelengths that correspond to the C-band (1530-1565nm) with zero-dispersion and low attenuation coefficient of 0.28 dB/km among feasible wavelength ranges for current signal transmission. Wavelengths within L-band (1565-1625nm) with a little lower quality than C-band can be used for assured services and best-effort services. To provide more sufficient QoS recovery with this wavelength assignment strategy, we also propose the service-differentiation by assigning service-specific wavelength ratio on each link in the network. Amount of total available wavelengths on each link is allocated to each service class (premium service: 10 %, assured service: 30 % and best-effort service: 60).

(c). Differentiated recovery schemes is applied for each se-

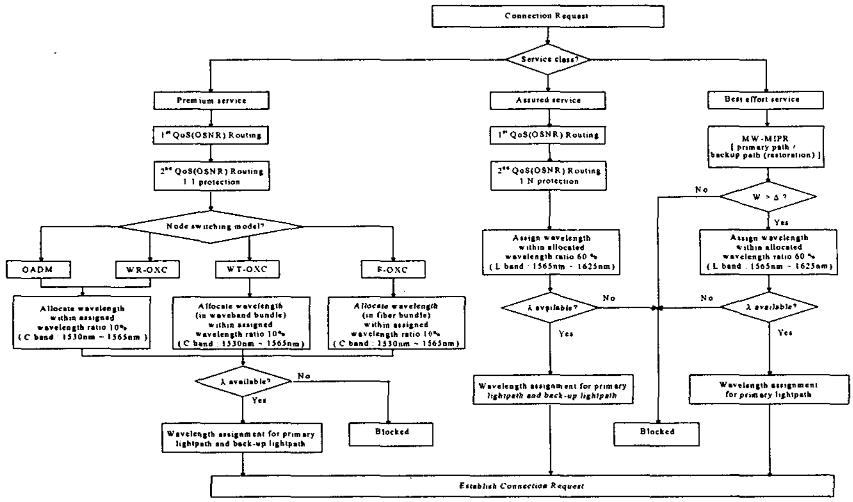

Fig. 4. Differentiated RWA mechanism with QoS Recovery (그림 4. QoS Recovery 를 지닌 차등적인 RWA 기법)

rvice to protect lightpath against a link or node failure. For premium services that command the highest priority and fast recovery time less than 50 msec, 1:1 protection is performed because it can guarantee 100 % survivability by quickly switching traffic to the dedicated back-up lightpath as soon as service degradation is detected. For assured service with lower QoS level than premium services, we apply 1:N protection with high wavelength utilization by sharing one back-up lightpath with N working paths. Generally, the back-up path (selected by recovery schemes) is path-disjointed or fiber-disjointed with primary path (determined by 1st QoS (OSNR) routing). And best-effort service is protected by restoration at IP level. If a failure occurs, then disrupted traffic can be compensated by TCP retransmission within from 100ms to a few seconds.

(d). Wavelength assignment for premium service is divided into four cases based on switching model of node as follows:

- *OADM*: Considering a physical fiber link breakdown, optical fiber cutting and OADM node fault at the fiber level, it might be better to allocate wavelength in a different fiber (fiber-disjoint back-up lightpath) for a back-up lightpath.
- *WR-OXC*: At this node without WC capability, incoming wavelength is the same as outgoing wavelength.
- *WT-OXC*: At this node with WC capability, wavelength assignment for a back-up lightpath should be accomplished in the same waveband path because a set of contiguous wavelengths is switched together to a new waveband.
- *F-OXC*: Considering reduction of distortion and allowance of tight separation for each link in fiber bundling, it might be better to allocate a corresponding wavelength in the same fiber bundle for a back-up lightpath.

Based on articles proposed in case (a), (b), (c), (d) and MW-MIPR algorithm, the differentiated RWA mechanism providing QoS recovery for each service class as illustrated in Fig. 4.

IV. Conclusion

In this paper, we proposed a new dynamic routing method (MW-MIPR) choosing a route that does not interfere too much with many potential future connection requests. This paper also proposed the differentiated RWA mechanisms with QoS recovery combined with MW-MIPR algorithm. Our work can achieve advanced global efficiency in wavelength utilization as well as guaranteed QoS recovery for various multimedia services in the next backbone networks based on DWDM. Proposed approach can be permitted generalized multi-protocol label switching (GMPLS) as control protocol of the next backbone networks. As a future research, we will study MW-MIPR algorithm based on sparse wavelength conversion network and expand differentiated RWA problem for service classes subdivided more detailed QoS level.

참고문헌

[1] B. Murherjee, Optical communication networks, McGraw-Hill Publishers, 1997.

[2] D. Zhou and S. Subramaniam, Survivability in Optical Networks, IEEE Network, vol. 14, no. 6, pp. 16 –23, Dec. 2000.

[3] H. Zang et al., "A Review of Routing and Wavelength Assignment Approaches for Wavelength Routed Optical WDM Networks," Optical Networks Magazine, vol. 1, no. 1, pp.47-60, Jan. 2000.

[4] M. Ma and M. Hamdi, "Providing Deterministic Quality-of-Service Guarantees on WDM Optical Networks," IEEE JSAC, vol. 18, no. 10, pp. 2072 –2083, Dec. 2000.